The EUMETSAT
Network of
Satellite Application
Facilities

OSI SAF

Ocean and Sea Ice

Low Earth Orbiter Sea Surface Temperature

Product User Manual

Version 3.1

December 2015

prepared by Météo France

DOCUMENT SIGNATURE TABLE

	Name	Date	Signature
Prepared by :	OSI SAF Project Team	10/12/2015	
Approved by :	OSI SAF Project Manager	10/12/2015	

DOCUMENTATION CHANGE RECORD

Issue / Revision	Date :	Change :	Description :
Version 1.0	22/10/07		First version.
Version 1.1	30/10/07	minor	Version taking into account EUMETSAT comments on version 1.0 : from Dominique Faucher on 23/10/07, Peter Schluess on 24/10/07 and Hans Bonekamp on 25/10/07.
Version 1.2	12/02/08		Description of the GRIB ed 2 included in appendix A.2
Version 1.3	31/07/08	minor	• section 5 presents the validation results (in place of Preliminary validation results) • Appendix A1 : A1.1 accounts for the modifications of the NetCDF global attributes that were suggested by EUMETSAT. A1.2 describes the final names adopted when the products became demonstrational.
Version 1.4	26/08/08	minor	Section 5, access to data added.
Version 1.5	09/01/09	minor	in the introduction data volume updated and explanation given on product confidence levels

Version 2.0	20/05/2009	major	The Metop/AVHRR Sea Surface Temperature Product User MANUAL is replaced by the Low Earth Orbiter Sea Surface Temperature Product User Manual, addressing the products derived from NOAA and MetOp AVHRR data, an in the future from NPP/VIIRS data. The NAR SST over one unique area, replacing the NAR SST over 7 areas, is addressed in the current PUM, while the old NAR SST over 7 sub-areas is addressed in the NOAA NAR PUM.
Version 2.1	04/11/2009		Version updated when NOAA-18 is replaced by NOAA-19. Introduction updated. Chapter on validation results removed (reference given to the Validation reports)
Version 2.2	12/05/2010		Modification in GRIB2 NAR SST description (Appendix A.2)
Version 2.3	05/06/2013		Modification in Appendix A.1
Version 2.4	30/08/2013		Updated version to include NAR SST products derived from NPP/VIIRS, and prepared for ORR
Version 2.5	30/09/2013		Updated version taking into account NAR SST VIIRS ORR RIDs. Information concerning Surface Temperature over selected lakes added in the section 1.1.
Version 2.6	15/04/2014		Updated version to include IASI derived SST products. Few changes taking into account IASI SST OSI-208 ORR RIDs.
Version 2.7	31/10/2014		IASI SST format updated : this product is available inL2P NetCDF only
Version 3.0	20/11/2015		Updated version for the ORR of AVHRR derived products OSI-201-b / OSI-202-b / OSI-204-b Information on processing chain removed because given in the ATBD.
Version 3.1	10/12/2015		Updated version taking into account the RIDs from reviewers of the Operational Readiness Review.

Table of Content

1. Introduction

1.1   Overview

The EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF) is a consortium constituted of Météo France as leading entity, and MET Norway, DMI, KNMI and IFREMER as co-operating entities.

The OSI SAF is routinely producing on a preoperational or operational basis a range of air-sea interface products, namely: wind, sea ice characteristics, Sea Surface Temperatures (SST) and radiative fluxes, Surface Solar Irradiance (SSI) and Downward Longwave Irradiance (DLI).

The products the OSI SAF is committed to produce in the framework of the current phase, the Continuous Development and Operations Phase 2 (CDOP2), are described in the Product Requirement Document [AD-5].

The characteristics of the products currently produced by the OSI SAF under pre-operational or operational status are provided in the Service Specification Document (SESP) [RD-1]). A Validation Report is available for each satellite [RD-2] ...statistics on product quality are provided in the Operations Quarterly Reports. All these documents are available on the Web site www.osi-saf.org.

All intellectual property rights of the OSI SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used. In case of using OSI SAF data for a publication, please acknowledge EUMETSAT contribution.

Users are highly recommended to register on the OSI SAF Web Site : www.osi-saf.org, in order to get access to useful information, documentation and links, news, service messages, and to the help desk.

The OSI SAF is committed to produce the following LEO satellite derived SST products :
-   the Global MetOp Sea Surface Temperature (GBL SST), a 12 hourly synthesis on a 0.05° global grid, referenced OSI-201-b,
-   the North Atlantic Region (NAR) Sea Surface Temperature 2 km stereopolar (NAR SST), referenced OSI-202-b, a 4-daily product derived from two satellites, i.e in 2013 from Metop and NPP. Those products are covering one unique area,
-   the full resolution MetOp Sea Surface Temperature metagranules (MGR SST), referenced OSI-204-b, a full resolution MetOp SST in satellite projection, corresponding to each granule of AVHRR data disseminated through EUMETCAST.
-   the MetOp IASI Sea Surface Temperature L2P files (IASI SST), referenced OSI-208, SST in satellite projection, consistent with the granules of AVHRR data.

These products will be referred to as GBL, NAR, MGR and IASI in this text, respectively. They include surface temperatures over selected lakes. They are derived using the standard SST algorithms with no commitment on the accuracy and validation.

Table 1 describes the characteristics of the OSI SAF SST products.

Table 1 : Characteristics of the OSI SAF SST products

Name	Coverage	Satelite	Reso-lution	Time charac-teristics	Formats	End to end Timeli-ness	Volume per unit : NetCDF	Volume per unit : GRIB(gzip) ed 2
GBL SST	Global	MetOp	0.05°	12h	NetCDF4 L3C GRIB2	6h	25 Mb	8.5 Mb
NAR SST	European Seas	MetOp	2 km	12h	NetCDF4 L3C GRIB2	6h	40 Mb	15 Mb
		NPP	2 km	12h	NetCDF4 L3C GRIB2	6h	20 Mb	3 MB
MGR SST	Global	MetOp	Full res. (1 km)	Every granule	NetCDF4 L2P	4h	10 Mb	N.A.
IASI	Global	MetOp	12 to 40km	Every granule	NetCDF4 L2P	4h	132 K	N.A.

L2P or L3C are in the NetCDF4 with internal compression format. In L2P and L3C, "2" refers to products in satellite projection and "3" to gridded products. The GRIB ed. 2 format is described in appendix 2. End-to-end timeliness is defined from the observation time of the last satellite input data of a product to its availability at the users site via EUMETCast.

Products in NetCDF4 are compliant with the GHRSST recommendations GDSV2.0 for IR derived products. As such the normalized Proximity Confidence Value (or quality level) scale fixes 6 values : 0 : unprocessed, 1 : cloudy , 2: bad, 3: suspect, 4: acceptable, 5 : excellent. Those values are good predictors of the errors. It is recommended not to use the confidence value 2 for quantitative use. Usable data are those with confidence values 3, 4 and 5.

1.2   Document structure

The main content of this manual is a description of the product contents and formats. It also briefly reviews the processing methods adopted, the algorithms used and the preliminary validation results.   The structure of the document is as follows :
1- This introduction
2- AVHRR processing chain and algorithm
3- NPP processing chain and algorithm
4- IASI processing chain and algorithm
5- Product description
6- Access to the products

Appendix A1, L2P and L3C format description
Appendix A2, format of the GRIB ed.2 product-
Appendix A3, accessing data by using the ECMWF GRIB API
Appendix A4, locating the NAR data by using PROJ4 library

1.3   Glossary

AATSR	Advanced Along Track Scanning Radiometer
AOD	Aerosol Optical Depth
Auxiliary data	Dynamic data that are used in the preparation of GHRSST L2P or L3C data products including wind speed, surface solar irradiance, aerosol optical depth and sea ice.

AVHRR	Advanced Very High Resolution Radiometer
AVH1B, AVH1C	Level-1 formats for AVHRR data. In AVH1B, calibration coefficients are included, and in AVH1C calibration coefficients are applied to provide reflectances and brightness temperatures
BT	Brightness temperature
CMS	Centre de Météorologie Spatiale (Météo France)
DMI	Danish meteorological Institute
DODS	Distributed Oceanographic Data System
ECMWF	European Centre for Medium-range Weather Forecasting
GDS	In situ and satellite data integration processing model
GEO	Geostationary Earth Orbit
GHRSST	The Groupe High Resolution Sea Surface Temperatur
GBL	Global
GMT	Generic Mapping Tool
GODAE	Global Ocean Data Assimilation Experiment
GOES	Geostationary operational environmental satellite
GRIB	GRIdded Binary format
GTS	Global transmission system
IASI	Infrared Atmospheric Sounding Interferometer
IR	Infra-Red
LEO	Low Earth Orbiter
L1	Level-1
L2	Level-2
L2P	Level-2 data with added confidence flags after checking for gross errors, consistency and timelines. This family of data products provides the highest quality data obtained from a single sensor for a given processing window. In satellite projection
L3C	Same as above, gridded
LAS	Live Access Server
MDS	Match up dataset
MET Norway	Norwegian Meteorological Institute
MF	Météo France
MGR	Metagranule
MSG	METEOSAT second Generation
NAR	North Atlantic Regional
NetCDF	Network Common Data Form
NOAA	National Ocean and Atmosphere Administration
NPP	National Polar-orbiting Partnership
NWP	Numerical Weather Prediction
QLV	Quality Level Value
Reference data	Pseudo static data and analysis products that are used by the GHRSST-PP (e.g., climatology maps, previous SST analysis (T-1))
SDI	Saharan Dust Index
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SSI	Surface Solar Irradiance
SSES	Single Sensor Error Statistics
SST	Sea Surface Temperature
VIIRS	Visible Infrared Imaging Radiometer Suite
XML	Extensible Mark-up Language

1.4   Applicable and reference document

1.4.1 Applicable documents

Reference	Title	Code
AD-1	GHRSST Data Processing Specification 2 release 5	https://www.ghrsst.org/documents/q/category/gds-documents/operational/
AD-2	IASI Level 2 product guide	EUM/OPS-EPS/MAN/04/0033 http://www.eumetsat.int/website/home/index.html
AD-3	IASI Level 2 Product Generation Specification	EPS.SYS.SPE.990013 http://www.eumetsat.int/website/home/index.html
AD-4	Single Sensor Error Statistic Scheme for IASI Level 2 Sea Surface Temperature	EUM/MET/DOC/11/0142 http://www.eumetsat.int/website/home/index.html
AD-5	PRD, Product Requirement Document	SAF/OSI/CDOP2/M-F/MGT/PL/2-001

1.4.2. Reference documents

Reference	Title	Code
RD-1	Service Specification Document	SAF/OSI/CDOP2/M-F/MGT/PL/2-003
RD-2	Validation report for OSI SAF Metop/AVHRR SST	SAF/OSI/CDOP2/M-F/SCI/TEC/234
RD-3	Algorithms Theoretical Basis Document for the Low Earth Orbiter Sea Surface Temperature Processing Chain	SAF/OSI/CDOP2/M-F/SCI/MA/216

2. AVHRR

This section presents a brief summary of the main features of the processing of the data, gives brief elements of validation and elaborates on the quality level associated with the data.

2.1 Processing chain and methods

The Low Earth Orbiter (LEO) processing chain ingests Metop-B/AVHRR granules (corresponding to 3 minutes of acquisition of the sensor). Each of these granules is processed and results in a workfile containing all intermediate information produced by the chain. The workfile are then used to elaborate the Matchup DataSet (MDS) and the OSI SAF products.
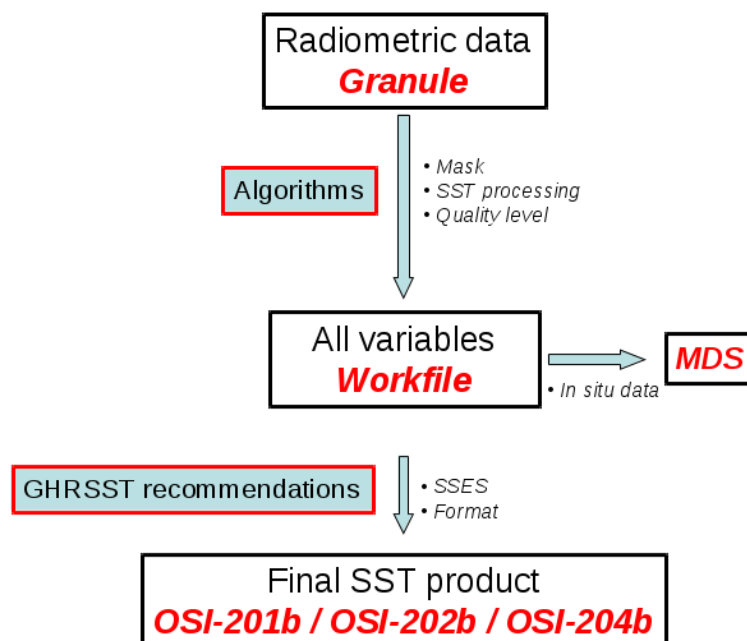

Figure 1 : schematic representation of the LEO processing chain.

The chain and methodologies are described in details in the Algorithms Theoretical Basis Document for the Low Earth Orbiter Sea Surface Temperature Processing Chain [RD.3].

2.2 Quality levels

Each pixel of any product is associated with a quality level which is an indication of the quality of the retrieval process. The definition of the quality levels adopts the recommendations of the GHRSST formalised through the GDS v2 document. For infrared derived SST six quality levels are defined. 0: unprocessed; 1: cloudy, 2: bad, 3: suspect, 4 acceptable, 5 excellent.

During the elaboration of SST products, many considerations are looked at in the making of the quality level:

- Difference of SST to SST climatology
- Difference of local value of SST gradient to climatology
- Distance to cloud
- Presence of dust aerosols
- Risk of having sea ice

- Satellite zenith angle
- Value of the algorithm correction

Each of these considerations is synthesized into an indicator which is tested against a threshold for the elaboration of the quality level. If every test is passed successfully the quality level will be set to the highest value.

For more details about the test indicators and quality levels, see [RD.3].

The most common source of degraded quality level is undetected clouds. Quality level 2 certainly contain cloudy pixels; quality level 3 may contain cloudy pixels whereas quality levels 4 and 5 very unlikely contain remaining clouds.

2.3 Elements of validations

A detailed validation is presented in the Validation report for OSI SAF Metop/AVHRR SST . Only the global statics of the comparison of AVHRR SST against drifting buoys measurements for a limited period of time are presented in *Table 2*. The methodology is described in [RD.2]. Results are presented per quality levels.

Table 2 : Global statistics of the comparison of AVHRR SST against drifting buoys measurements for the period: 19/04/2015 – 30/10/2015.

Quality level	Day			Night		
	number of cases	Bias (K)	standard deviation (K)	number of cases	bias (K)	standard deviation (K)
5	13717	-0.04	0.39	15407	-0.01	0.32
4	16817	-0.10	0.50	17952	-0.10	0.46
3	40433	-0.26	0.59	26637	-0.41	0.60
2	46722	-2.01	2.04	63958	-3.37	2.11

3. NPP processing chain and algorithms

An operational processing chain to derive SST fields from data of the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard Suomi National Polar-orbiting Partnership (NPP) has been implemented. These data have been acquired at Centre de Météorologie Spatiale (CMS) in Lannion (Brittany) in direct readout mode since April 2012.
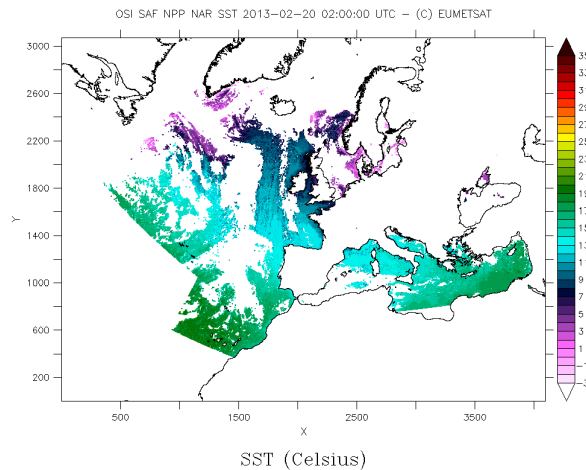

Figure 2 : Example of the North Atlantic Regional (NAR) product coverage by NPP/VIIRS SST data

As far as NPP data processing is concerned, OSI SAF is committed to produce the 2 km polar stereographic North Atlantic Regional product (NAR, cf Figure 2), as a continuity to the present NOAA/AVHRR derived OSI SAF NAR products. This section describes the VIIRS SST processing chain and algorithms that have been developed at CMS.

3.1 NPP/VIIRS processing chain

3.1.1 Overview

The CMS VIIRS processing chain is based on the experience gained over several years in processing Metop/AVHRR and geostationary data at CMS. It includes the following main steps (see Figure 3) :
- preprocessing: ingestion of the VIIRS L1C (L1B + cloud mask) data
- cloud mask control
- SST calculations
- quality level value determination,

that will be detailed in section 3.1.2 below.

One significant difference with the AVHRR chain is that cloud mask control does not alter the original MAIA mask, whereas in the AVHRR chain, dubious pixels are masked during the cloud mask control step. This is conform to GHRSST recommendations and the same principle has been adopted in the CMS geostationary SST chain.
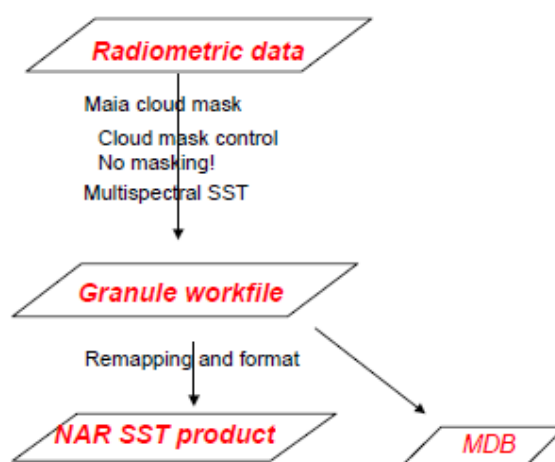
Figure 3 : Schematic diagram of the operational NPP/VIIRS SST chain

Aside from sea/lake/land mask and front climatology, similar to those used in the AVHRR chains, a new SST climatological information is used by the chain:

SST climatology: Mean and minimum climatological SST values are used in the SST calculations and the cloud mask control. We have used the mean and minimum daily SST climatology, at 0.05° resolution, derived from the OSTIA SST reanalysis (Roberts-Jones et al, 2012)

3.1.2 Main processing steps

Preprocessing: This step delivers granules corresponding to a fixed time period (86 seconds). Radiometric data are acquired at CMS in direct readout which induces a coverage limited to European seas (Figure 2).

The outputs of the acquisition station are converted into Raw Data Record (RDR) using the NASA Real-time Software Processing System (RT-SPTS). The Community Satellite Processing Package (CSPP) is then used for data calibration and geolocalisation.

A cloud mask (MAIA) is derived from the radiometric data. MAIA is a threshold based cloud mask originally developed for the AVHRR and upgraded and adapted to VIIRS processing (Lavanant, 2012). In the preprocessing step, a special attention has been paid to defining pixel adjacency over several scan lines by extending the capacities of the Common Adjacency Software, as shown in Figure 4. Pixel adjacency is essential when calculating a gradient or defining a box for smoothing or validation.

Figure 4 : Raw 11micron brightness temperature (in K) image (left); after adjacency algorithm is applied (right)
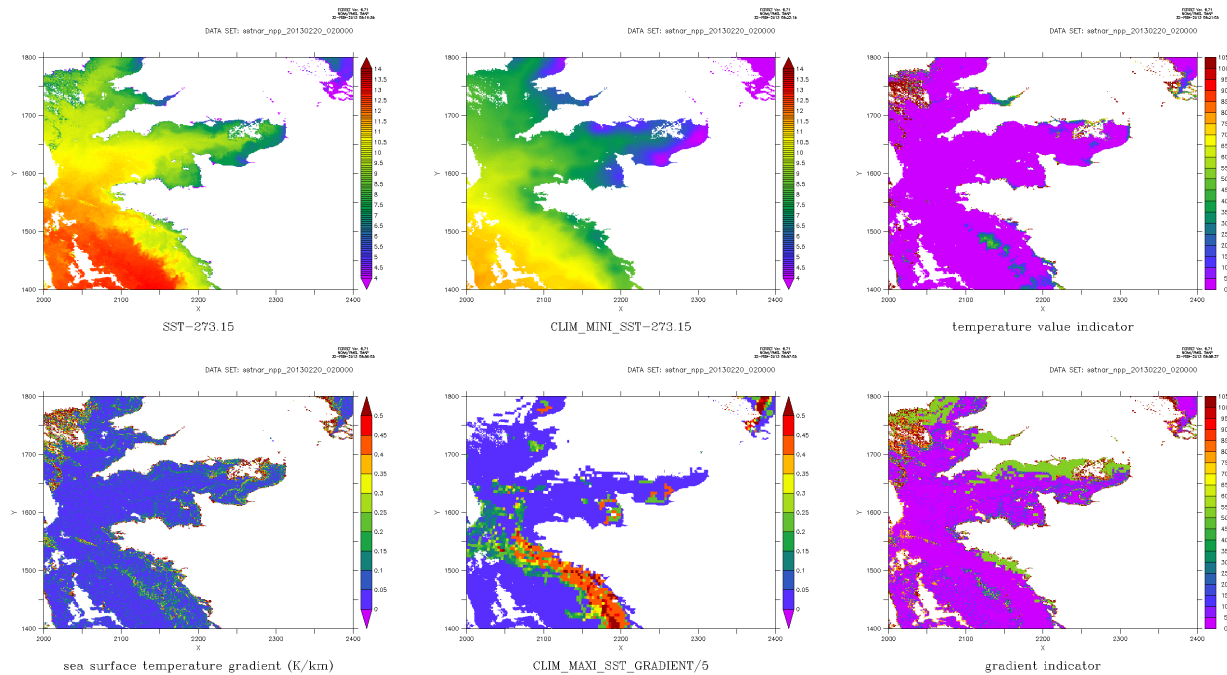

Figure 5 : Subset of the NAR area over Brittany on the 20th of February 2013:Top: SST (in °C), minimum temperature climatology (in °C), temperature value indicator; Bottom: SST gradient (in K/km), gradient climatology (in K/km), gradient indicator
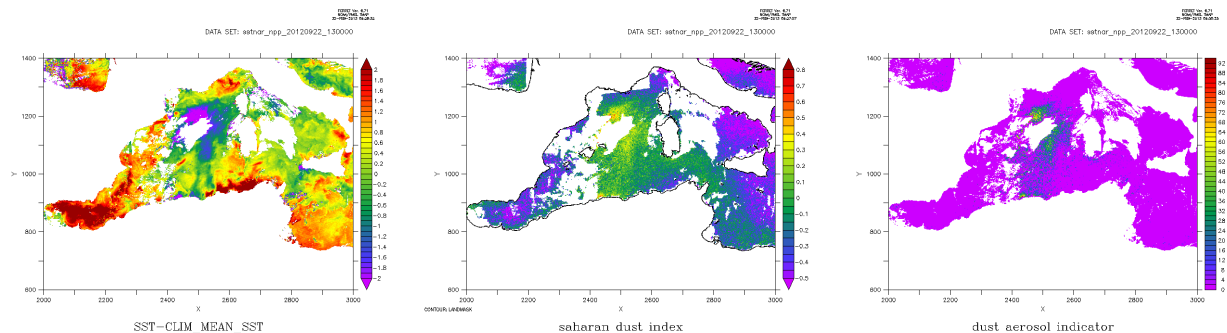
Figure 6 : Subset of the NAR area over the western Mediterranean Sea on the 22nd of September 2012: SST – mean climatology (in K) of the day, SEVIRI Saharan Dust Index, dust indicator

A workfile including the radiometric data and creating all the further requested variables is built for this granule.

Cloud mask control: Similarly to what is done in the CMS AVHRR SST chain, a series of tests has been defined that consider various quantities such as the local values of gradient,

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temperature, probability of ice, Saharan dust. The difference with the AVHRR chain is that no mask control step is critical (none results in additional masking). As a consequence, the order of the tests does not matter. For each test, a test indicator has been defined by comparison of the tested quantity (test_value) with a limit value (limit_value) and a critical value (critical_value). Outside this range of values either there is no problem, or the risk of errors is too high. Similarly to the AVHRR chain, the test indicator is defined as :

test_indicator= 100 x (test_value-limit_value)/ (critical_value – limit_value)   (1)

indicator values below 0, or above 100 are assigned to 0 and 100, respectively.

This approach enables the homogenization of the test results on a unique scale :
0 : no problem ;]0-100[: potential problem ; 100 : critical problem.

The following indicators are used :

- Local temperature value indicator: the calculated SST is compared to limit and critical values of the temperature deduced from the OSTIA world SST climatology (see above), by adding margins to the local value of the minimum SST climatology. These margins are function of the interannual standard deviation of the temperatures, of distance to cloud and distance to coast (see Figure 5).
- Gradient indicator: derived from the difference between the local SST gradients and the corresponding maximum climatological values calculated from the world Atlas of thermal fronts (see Figure 5). The limit value of this quantity corresponds to the SST noise equivalent gradient value. The critical value is a plausible margin which is reduced in the vicinity of cloud, so that for a pixel close to a cloud the critical value is more easily reached than far from clouds. The gradient indicator is calculated from the limit and critical values according to equation (1). In the present version, the gradient indicator is calculated by night only, because the use of visible channel allows in principle an efficient masking of the cloud edges and because diurnal warming may introduce local fronts that are not recorded in the climatology.
- Saharan dust indicator (Figure 6): As in the AVHRR chain it is based on the use of the Saharan Dust Index or the NAAPS Aerosols Optical Depth where the SEVIRI information is not available. A nighttime SDI has been defined for application to VIIRS data (Le Borgne et al, 2013) but the operational VIIRS chain still uses the SEVIRI derived SDI.
- Ice indicator: derived from the probability of ice calculated by applying the MET Norway ice probability method (Eastwood and Andersen, 2007), with VIIRS adapted parameters (S. Eastwood personal communication)

For each indicator, limit and critical values were adjusted considering their impact on the preliminary validation results. As in the AVHRR chain, the synthesis of all the test indicators is used to reflect the quality of the mask (see quality level determination below).

SST calculation: Two SST calculations are made: one in the context of cloud mask control, using the pixel values, and the final calculation using a smoothed atmospheric correction term over reliable data.

Quality level value determination: The value of the quality level is determined by examining and combining the values of indicators set along the processing of SST. We use the concept of indicator to quantify, in an empirical way, the risk of having an error in the SST retrieval because of uncertainties in algorithms or ancillary variables. Indicators are set to a

value between 0 and 100 determined by tests performed on the following quantities: probability of having sea ice, difference between retrieved SST and SST local gradients and climatology of SST and SST local gradients, satellite zenith angle and dust aerosols. More information can be found in [RD.3] (this document describes the methodology for Metop OSI SAF processing chain, it is the same methodology used in NPP chain but the tested quantities are the one listed above only). Quality levels range from 2 to 5. The quality of the retrieved SST increases as quality level increases. **It is recommended not to use quality 2 level data for quantitative use.**

Table 3 : Meaning of Quality level values.

QLV	0	1	2	3	4	5
Meaning	unprocessed	cloudy	bad	suspect	acceptable	excellent

3.2 NPP/VIIRS Algorithms

Based on Francois et al, 2002 and experiences gained with Metop/AVHRR or SEVIRI, the following algorithms have been selected for VIIRS SST retrieval :

NLC : SST = $(a + b\ S_\theta)\ T_{11} + (c + d\ S_\theta + e\ T_{CLI})\ (T_{11} - T_{12}) + f + g\ S_\theta$, for daytime and

T37_1 : SST = $(a + b\ S_\theta)\ T_{37} + (c + d\ S_\theta)\ (T_{11} - T_{12}) + e + f\ S_\theta$, for nighttime applications

S_θ = $\sec(\theta) - 1$, θ is the satellite zenith angle and T_{CLI} is the mean climatological SST.

Table 4 : Coefficients of the non linear split window (NLC) and triple window (T37_1) algorithms for NPP/VIIRS, with all temperatures expressed in degree Celsius.

	a	b	c	d	e	f	g
NLC	1.00055	0.00852	1.29073	0.77930	0.04010	1.05141	0.81520
T37_1	1.01612	0.01709	0.85154	0.36969	1.13960	0.82285	-

NLC is applied for sun zenith angles below 90° and T37_1 for sun zenith angles above 110°. In twilight conditions, SST is calculated through a weighted mean of daytime and nighttime algorithms. The coefficients of the algorithms have been derived on a simulated brightness temperatures data base described in Francois et al, 2002. The initial version of the coefficients are given in *Table 4*. A SDI correction term is calculated as a quadratic function of the SDI values, for 0.1<SDI<0.8. This correction depends on the algorithm used. No corrections are made when there is no SEVIRI observations. The same algorithms are applied to retrieve surface temperature over sea and lakes. A validation report (Le Borgne et al, 2013) is available, and operational validation results are made routinely available on the OSI SAF website

4. Metop/IASI Processing chain and algorithms

This section presents the physical and statistical basis for the retrieval of Sea Surface Temperature (SST) from the Infrared Atmospheric Sounding Interferometer (IASI) on the Metop satellites, referencing applicable documents where appropriate. The IASI SST L2P is produced by the OSI SAF to be compliant with the specification from the Group for High Resolution Sea Surface Temperatures (GHRSST) [AD-1] based upon skin sea surface temperatures derived from IASI by EUMETSAT central facilities. These skin SSTs are produced from the EUMETSAT IASI L2 Product Processing Facility (PPF) and stored at EUMETSAT as IASI L2Pcore (reduced GHRSST format). Since the algorithm development is performed at EUMETSAT, this section references the algorithm description documents available from EUMETSAT, and gives an overview of the additions to the product given by the OSI SAF. The applicable documents are listed in section 1.4 of this Product User Manual.

4.1 Overview and background

Skin sea surface temperatures from IASI have been produced at EUMETSAT in GHRSST Data Specification 2.0 [AD-1] L2Pcore format since March 2011. The SSTs are the same as those available since April 2008 from the IASI L2 Product Processing Facility (PPF) at EUMETSAT [AD-2]. The IASI L2Pcore SSTs products contain skin SSTs, Sensor Specific Error Statistics [AD-4], quality levels, flags and collocated model surface winds. These IASI L2Pcore SSTs are augmented by the OSI SAF to produce full GHRSST-compliant L2P files, by the addition of other auxiliary data including sea-ice, aerosol and SST background fields.

Details of the IASI L2Pcore product, used as an input to the OSI SAF production of the full IASI L2P file can be found in [AD-3] with further details contained in the product guide [AD-2]. Previous validation results of the IASI skin sea surface temperatures are documented in August et al, 2012 and O'Carroll et al, 2012.

4.2 Algorithm overview

Details on the retrieval for surface temperature are given within section 5 of [AD-3].

An essential feature of the GHRSST L2P specification is the Sensor Specific Error Statistic (SSES) field. These are observational error estimates provided at pixel level as a bias and standard deviation, traditionally derived from comparisons with drifting buoys. Each observation is assigned a quality level from 0 to 5, where 0 is missing data, 1 is bad data (such as cloud), 2 is the worst useable data, and 5 is the best quality. The SSES bias and standard deviation are calculated for each quality level from analysing differences between satellite SSTs collocated with drifting buoys in a match-up database. Further details on the methodology and estimation of the SSES for IASI SSTs can be found in [AD-4].

4.3 Algorithm description

The theoretical description of the algorithm can be found in the EUMETSAT document "IASI Level 2 Product Generation Specification" [AD-3]. A description of the SSES can be found in the EUMETSAT document "Single Sensor Error Statistic Scheme for IASI Level 2 Sea Surface Temperatures" [AD-4].

4.4 Constraints, assumptions and limitations

The constraints, assumptions and limitations are included in the EUMETSAT document "IASI Level 2 Product Generation Specification" [AD-3] in section 5.

4.5 Implementation of IASI L2P at the EUMETSAT OSI SAF

Core IASI SST files are produced at the EUMETSAT central facility . They are pulled via ftp by CMS in near real time.

At CMS, they are complemented with the following variables: DT_analysis (source : OSTIA) ; Aerosol Dynamic Indicator (source : NAAPS Aerosol Optical Depth) ; Sea Ice Fraction (source : OSI SAF). These ancillary data are the nearest in space and time to the input SST pixel among available datasets at processing time. The maximum time offset between these ancillary data and the SST data are 36 h for the DT_analysis, 24h for the Aerosol Dynamic Indicator and 72 h for the Sea Ice Fraction. NB : The wind variable has been already filled up at EUMETSAT.

They are formatted according to GDSV2.0 under product string : « IASI_SST_Metop_A ». This format is NetCDF4 with internal compression. They are disseminated through EUMETCast and Ifremer FTP server.

5. Product description

5.1 Case of the MGR SST and GBL SST

At the end of the processing a workfile in NetCDF is filled up for each metagranule and contains :

- location and illumination conditions,
- reflectances and brightness temperatures,
- MAIA original information,
- static data (landmask, climatology values,..),
- dynamic data (SEVIRI SDI, NAAPS AOD,..),
- intermediate calculation values (gradients, indicators..),
- final results (SST, missing reasons, QLV,..).

These workfiles are produced and archived at CMS for validation, control and further use. All the final products are derived from these workfiles.

The SST metagranules are sent to IFREMER in L2P format for further usages. Note that the processing time from the ingestion to the delivery in L2P format is about 1 minute for a 3 minute granule.

The GBL products is a 12 hourly synthesis centred at 0000 and 1200 UTC. They are built progressively (when a new metagranule is ready to contribute) as follows:
- the metagranule pixel variables corresponding to one global grid point are averaged after selection of the best QLV,
- the resulting values are candidate for the global file, but may compete with values already in place (originating from a previous metagranule). In such a case the selection is made according to the following criteria (with this priority order):
  - best QLV,
  - nighttime cases have priority,
  - lowest satellite zenith angle.

5.2 Case of the NAR SST derived from MetOp AVHRR or NPP/VIIRS (NAR SST)

The NAR 2 km resolution products (Figure 8) are made twice a day for each satellite over the European waters. Note the difference in coverage for Metop (data acquisition through EUMETCast) and NPP (data acquisition through Direct readout). The same rules as those adopted for the global product are applied in this case. Prior to entering the contribution scheme, the metagranules are filtered according to their time: they must be dated to within DT from the NAR nominal times (e.g. 1000 UTC and 2000 UTC for Metop). At present DT=4.5h.

5.3 Geographical definitions

MGR:
Projection: satellite projection
Resolution: full AVHRR resolution (1 km)
Size: 2048 columns, 1080 lines corresponding to 3 minutes of data acquisition; note that the number of lines may vary.

NAR:
Projection: Polar stereographic projection defined with an elliptical earth (equatorial radius: 6378.388 km; polar radius: 6356.912 km), y axis is meridian 0.
Resolution: 2 km at 45 N
Size: 3072 columns, 4096 lines
Longitude and latitude limits (westernmost and easternmost longitudes; southernmost and northernmost latitudes): 76.02°W, 72.97°E, 13.59 °N, 78.24°N

GBL:
Projection: linear scaling in latitude and longitude
Resolution: 0.05 degree in latitude and longitude
Size: 7200 columns, 3600 lines
Longitude and latitude limits : 180°W, 180°E, 90° S, 90°N

IASI:
Projection: satellite projection
Resolution: full IASI resolution
Size: 120 columns, 23 lines corresponding to 3 minutes of data acquisition; note that the number of lines may vary.

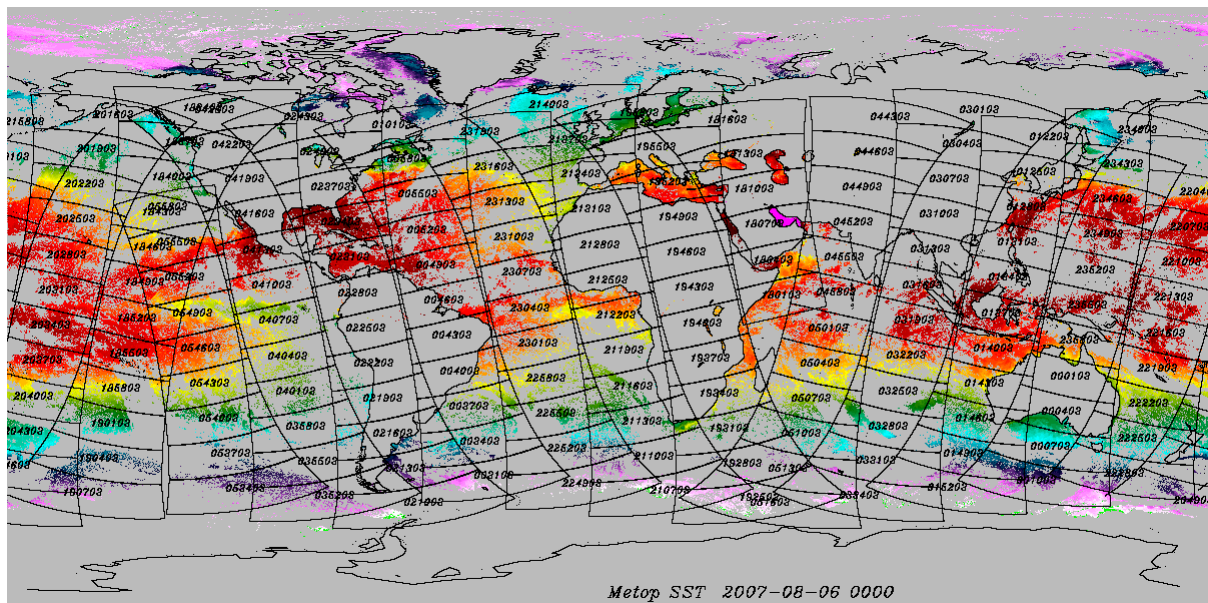Longitude and latitude limits : 180°W, 180°E, 90° S, 90°N

Figure 7 : 0.05° resolution global product on the 6th of August at 0000 UTC, showing the contributing MetOp metagranules superimposed
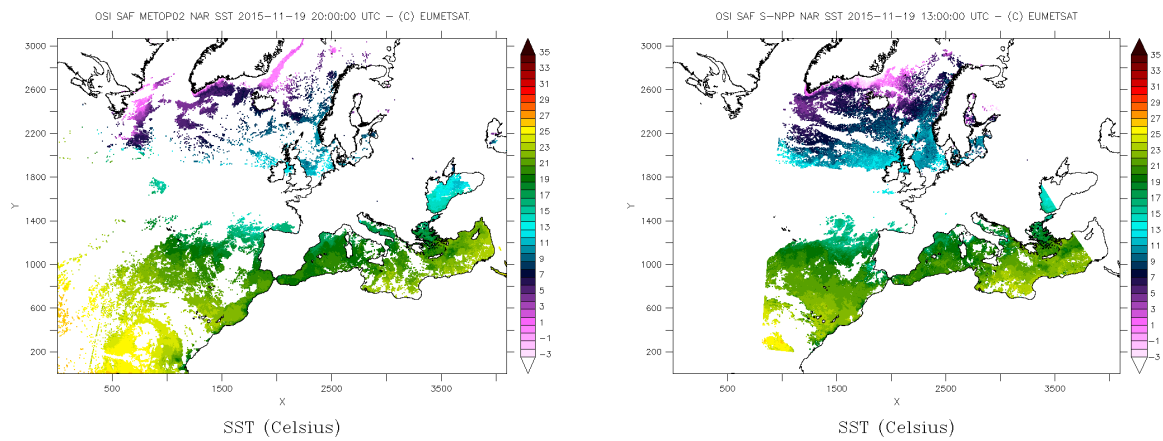
Figure 8 : Example of 2 km resolution NAR product on 19th November 2015: left: Metop; right NPP

The L2P or L3C format description is provided in appendix A.1.

The GRIB format is provided in appendix 2.

6. Access to the products

6.1 Access to Near real time products

Access to the Near real time products is indicated in the following table :

Name and ref. of the product	Format	Access
GBL SST (OSI-201-b)	L3C NetCDF	IFREMER FTP server
GBL SST (OSI-201-b)	GRIB2	EUMETCast
NAR SST (OSI-202-b)	L3C NetCDF	IFREMER FTP server
NAR SST (OSI-202-b)	GRIB2	EUMETCast
MGR SST (OSI-204-b)	L2P NetCDF	IFREMER FTP server / EUMETCast
IASI SST (OSI-208)	L2P NetCDF	IFREMER FTP server / EUMETCast

Notes :

IFREMER FTP server is accessible to users registered on the OSISAF web site, (http://www.osi-saf.org) at the following address :
ftp://eftp.ifremer.fr/cersat-rt/project/osi-saf/
Users rights are provided on request at osi-saf.manager@meteo.fr

6.2 Access to archived products

Access to the archived products is indicated in the following table :

Name and ref. of the product	Format	Access
GBL SST (OSI-201)	L3C NetCDF	IFREMER FTP server
GBL SST (OSI-201)	GRIB2	EDC
NAR SST (OSI-202)	L3C NetCDF	IFREMER FTP server
NAR SST (OSI-202)	GRIB2	EDC
MGR SST (OSI-204)	L2P NetCDF	IFREMER FTP server
IASI SST (OSI-208)	L2P NetCDF	IFREMER FTP server / EDC

Notes :

EDC is EUMETSAT Data Center (new name of UMARF)

IFREMER FTP server is accessible to users registered on the OSISAF web site, (http://www.osi-saf.org) at the following address :
ftp://eftp.ifremer.fr/cersat-rt/project/osi-saf/
Users rights are provided on request at osi-saf.manager@meteo.fr

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Appendix A.1. L2P and L3C format description

The GHRSST data files have been chosen to follow the Climate and Forecast NetCDF conventions because these conventions provide a practical standard for storing oceanographic data, and have already been adopted for the Data Sharing Pilot project within GODAE. The NetCDF data format is extremely flexible, self describing and has been adopted as a de-facto standard for many operational oceanography systems.

The L2P and L3C EUMETSAT OSI SAF LEO SST product format is compliant with the GHRSST Data Processing Specification (GDS) document. This document has evolved from version 1.7 to version 2.0. The OSI SAF LEO SST products have evolved accordingly. They were compliant with GDS version 1.7 till the 3rd of July 2013. Since then they have been compliant with GDS version 2.0. The table below gives an overview of the GHRSST data products specified by the version 2.0 of the GDS.

Table 6-1 GHRSST data products specified by the GDS 2.0.

SST Product	L2 Pre-Processed [Section 8]	L3 Uncollated [Section 1010]	L3 Collated [Section 10]	L3 Super-collated [Section 10]	Analyzed SST [Section 11]	GHRSST Multi-Product Ensemble SST [Section 12]
Acronym	L2P	L3U	L3C	L3S	L4	GMPE
Description	Geophysical variables derived from Level 1 source data at the same resolution and location as the Level 1 data, typically in a satellite projection with geographic information. These data form the fundamental basis for higher-level GHRSST products and require ancillary data and uncertainty estimates. No adjustments to input SST have been made.	L2 data granules remapped to a space grid without combining any observations from overlapping orbits.	SST measurements combined from a single instrument into a space-time grid. Multiple passes/scenes of data can be combined. Adjustments may be made to input SST data.	SST measurements combined from multiple instruments into a space-time grid. Multiple passes/scenes of data are combined. Adjustments may be made to input SST data.	Data sets created from the analysis of lower level data that results in gridded, gap-free products. SST data generated from multiple sources of satellite data using optimal interpolation are an example of L4 GHRSST products	GMPE provides ensemble information about various L4 data products. It provides gridded, gap-free SST information as well as information about the spread in the various L4 products.
		L3 GHRSST products do not use analysis or interpolation procedures to fill gaps where no observations are available				
Grid specification	Native to SST data format	Defined by data provider	Defined by data provider	Defined by data provider	Defined by data provider	Defined by data provider
Temporal resolution	Native to SST data stream	Native to data stream	Defined by data provider	Defined by data provider	Defined by data provider	Defined by data provider
Delivery timescale	As available, Ideally within 3 hours from acquisition at satellite	As available, Ideally within 3 hours from acquisition at satellite	As available, Ideally within 3 hours from acquisition at satellite	As available, Ideally within 3 hours from acquisition at satellite	Analyzed product processing window as defined by data provider.	As available, ideally within 24 hours of the input L4 products being available.
Target accuracy	Native to data stream	Native to data stream	<0.4 K	<0.4 K	< 0.4 K absolute, 0.1 K relative	< 0.4 K
Error statistics	Native to data stream if available, sensor specific error statistics otherwise	Native to data stream if available, sensor specific error statistics otherwise	Derived from input data for each output grid point.	Derived from input data for each output grid point.	Analysis error defined by data provider for each output grid point (no input data statistics are retained)	The standard deviation of the input L4 analyses is provided. This is not an error estimate, but provides some idea of uncertainty.
Coverage	Native to data stream	Native to data stream	Defined by data provider	Defined by data provider	Defined by data provider	Defined by data provider

The corresponding document is available through :

https://www.ghrsst.org/documents/q/category/gds-documents/operational/GDS20r5.pdf

Any future update of the GDS format will be found under this directory.

Users must be aware that GDS version 1.7 compliant data were compressed using bzip2 compression. **The GDS version 2.0 products are NetCDF4 classic model files using internal compression feature**.

Appendix A.2: Format of the GRIB ed. 2 product

The GRIB products are encoded following the rules defined in FM 92 GRIB Edition 2 (version 3 02/11/2005).
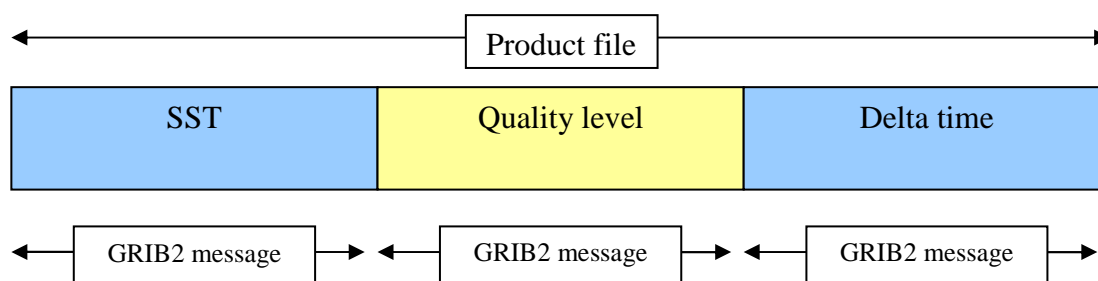
There are two types of GRIB ed. 2 products:
- GBL (Global) product
- NAR (Near Atlantic Regional) product

A2.1 File structure

A GRIB ed. 2 product is delivered as a single file in which three GRIB2 messages are concatenated.:

The first GRIB2 message provides the SST data, the second one provides the quality level data and the last one provides the delta time data.

Note : The multi-fields capability of the GRIB2 format has <u>not</u> been used for the sake of the simplicity and also because it would have mixed a standard parameter (SST) with non standard ones ("confidence level" and "delta time").

The Appendix A.3 gives some hints to access data by using the ECMWF GRIB API.

A2.2 Encoding characteristics

Hereafter are described the most relevant and specific information of each section of the GRIB2 messages. Unless otherwise specified the values are given for both types of product (GBL or NAR) or of data (SST, confidence level, delta time)
Section 0 (Indicator Section)

Octet. No.	Meaning	Value	Notes
7	Discipline	10	Oceanographics products (cf. Table 0.0)

All the three messages have the same Indicator Section.
Section 1 (Identification Section)

Octet. No.	Meaning	Value	Notes
6-7	Identification of originating/generating centre	211	Lannion (see Common Code Table C-1)
8-9	Identification of originating/generating sub-centre	0	
12	Significance of Reference Time	3	Observation time (see Code Table 1.2)
13-19	Reference time of data	variable and product specific	Individual pixels time can be derived from reference time by using the Delta Time message data. For GBL products the reference hour is either 00:00 or 12:00 UTC. For Metop02 NAR products the reference hour is either 10:00 or 20:00 UTC For NOAA-19 NAR products the reference hour is either 03:00 or 13:00 UTC For NPP NAR products the reference hour is either 02:00 or 13:00 UTC *In the past, for NOAA-18 NAR products the reference hour was either 02:00 or 12:00 UTC*

All the three messages have the same Identification Section.
Section 2 (Local Use Section)

There is no section 2 in either message.

Section 3 (Grid Identification Section)

The "Grid Definition Template Number" (Octets No. 13-14) depends on the product type :

- for GBL product it is coded 0 : Latitude/longitude (see Code Table 3.1)
- for NAR product it is coded 20 : Polar stereographic (see Code Table 3.1)

In both cases data have been organized such as the "scanning mode" flag is 0 (Points of first row scan in the +i direction, points of the first column scan in the –j direction).

For more details, see the "Grid characteristics" paragraph below.

All the three messages have the same Grid Identification Section.

Section 4 (Product Definition Section)

Octet. No.	Meaning	Value	Notes
8-9	Product definition template number	31	Satellite product (see Code Table 4.0) Since Ed. 2 version 3 product definition 4.30 is deprecated . Template 4.31 should used instead.
10	Parameter category	data specific	SST data : 3 (Surface properties) Confidence level data : 192 (Reserved for local use) Delta time data : 192 (Reserved for local use) (see Code Table 4.1 for Product Discipline 10)
11	Parameter number	data specific	SST data : 0 Water temperature (see Code Table 4.2 for Product Discipline 10 / Parameter category 3) Confidence level data : 1 (Since confidence level has no entry in the code table, a local category values is to be used) Delta time data : 2 (Since delta time has no entry in the code table, a local category values is to be used)
13	Observation generating processing identifier	220 or 229	220 : product from the operational processing chain 229 : product from the test processing chain
14	Number of contributing spectral bands	3	For NOAA and Metop products only
15-25	Definition of spectral band 1		IR3.7
26-36	Definition of spectral band 2		IR10.8
37-47	Definition of spectral band 3	591	IR12.0

Inside the definition of the contributing spectral bands, the satellite series, the satellite number and the instrument type are encoded as per BUFR code tables :

satellite series : (see BUFR code table 0 02 020)
EPS is coded 61
TIROS 2 is coded 3

satellite number : (see BUFR code table 0 01 007)
Metop02 is coded 4
Metop01 is coded 3
NOAA18 is coded 209
NOAA19 is coded 223
NPP is coded 224
instrument type : (see BUFR code table 0 02 019)
AVHRR/3 is coded 591
VIIRS is coded 616

Section 5 (Data Representation Section)

Octet. No.	Meaning	Value	Notes
10-11	Data Representation Template Number	0	Grid point data-simple packing (see Code Table 5.0)

The product are encoded so that the Decimal scale factor and the Numbers of bits are invariant for a given data type. The following table gives these values for each data type.

Octet No.		SST	Confidence level	Delta time
18-19	Decimal scale factor	2	0	0
20	Number of bits	12	2	10

The reference value (Octet No 12-15) and the Binary scale factor (Octet No 16-17) may vary, though the binary scale factor should be 0 in most cases.
Section 6 (Bit Map Section)

The "Bit-map indicator" (Octet No. 6) is always 0 (a bit-map applies to this product). All data are missing on land pixels and on the water pixels where SST has not been computed.

All the three messages have the same bit map section.
Section 7 (Data Section)

The section 7 provides the data according to the Data Representation Template number given in octets 10-11 of Section 5.

The following table gives the meanings of the three types of data :

data	meanings
SST	Water temperature (in deg. K)

Quality level	An index value with the following meanings :
	2: bad 3: suspect 4: acceptable 5: excellent (note: unprocessed and masked cases are set as missing values)
Delta time	Signed delta time (in minutes) from Reference time of Data (given in Section 1). Individual pixel can be determined as follows : Pixel time = Reference time of Data + Delta time

A2.3 Grid characteristics

GBL product

Projection	Equidistant cylindrical
Resolution	0.05 °
Size	7200 columns x 3600 lines
Upper left corner pixel center	89.975 N / 179.975 W

Converting between pixel coordinates (column, line) and geographical ones (longitude,latitude) is straithforward by using the linear relations :

```
longitude = -179.975 + 0.05 ( column – 1)
latitude  =   89.975 – 0.05 ( line   – 1)
```

where :

- longitude and latitude are in degrees,
- $1 \leq$ column ≤ 7200
- $1 \leq$ line ≤ 3600

NAR product

Projection	Polar stereographic true at 45°N
Resolution	2 km
Size	4096 columns x 3072 lines
Central meridian	0°
Upper left corner pixel center	43.765273°N / 76.018069°W

Converting between pixel coordinates (column, line) and geographical ones (longitude,latitude) can be done using the PROJ4 library cartographic projection library with the following "proj4 string" :

```
+proj=stere  +a=6356775  +  b=6356775   +lat_0=90  +lat_ts=45
+lon_0=0
```

The Appendix A.4 gives two demo programs using the PROJ4 library for that purpose.

Appendix A.3 : Accessing data by using the ECMWF GRIB API

The ECMWF GRIB API is an application program interface accessible from C and FORTRAN programs developed for encoding and decoding WMO FM-92 GRIB edition 1 and edition 2 messages. A useful set of command line tools is also provided to give quick access to grib messages.

For more details see :

 http://www.ecmwf.int/products/data/software/grib_api.html

The following examples have been tested with the 1.3.0 version of the GRIB API.

A3.1 Definition of template 4.31

In order to decode properly the GBL and NAR GRIB2 file with the grib_api software a file named template.4.31.def should be added in the $GRIB_DEFINITION_PATH/grib2 directory, where $GRIB_DEFINITION_PATH is the environment variable pointing to the definitions   files   to   be   used   with   grib_api   (typically $INSTALL_DIR/share_grib_api/definitions if $INSTALL_DIR is the directory where grib_api has been installed. This definition file should content the following text :

```
# For grib2 to grib1 convertion
constant dataRepresentationType = 90;


# START 2/template.4.31 --------------------------------------------------
# TEMPLATE 4.31, Satellite Product
#  Parameter category
codetable[1] parameterCategory 'grib2/4.1.[discipline:l].table';

#  Parameter number
codetable[1] parameterNumber
'grib2/4.2.[discipline:l].[parameterCategory:l].table';

#  Type of generating process
codetable[1] typeOfGeneratingProcess 'grib2/4.3.table';

#  Observation generating process identifier
# (defined by originating Centres)
unsigned[1] observationGeneratingProcessIdentifier ;

#  Number of contributing spectral bands
# (NB)

unsigned[1] numberOfContributingSpectralBands  ;

unsigned[2] satelliteSerie1 ;
unsigned[2] satelliteNumber1 ;
```

```
unsigned[2] instrumentType1 ;
unsigned[1] scaleFactorOfCentralWaveNumber1 = missing() : can_be_missing ;
unsigned[4] scaledValueOfCentralWaveNumber1 = missing() : can_be_missing ;


unsigned[2] satelliteSerie2 ;
unsigned[2] satelliteNumber2 ;
unsigned[2] instrumentType2 ;
unsigned[1] scaleFactorOfCentralWaveNumber2 = missing() : can_be_missing ;
unsigned[4] scaledValueOfCentralWaveNumber2 = missing() : can_be_missing ;


unsigned[2] satelliteSerie3 ;
unsigned[2] satelliteNumber3 ;
unsigned[2] instrumentType3;
unsigned[1] scaleFactorOfCentralWaveNumber3 = missing() : can_be_missing ;
unsigned[4] scaledValueOfCentralWaveNumber3 = missing() : can_be_missing ;



# END   2/template.4.31 ----------------------------------------------
```

A3.2 How to split a GRIB2 product file

One simple way to split a GBL or NAR GRIB2 file into the three GRIB2 messages (SST, Confidence level, Delta time) is to use the grib_copy tool provided in the GRIB API distribution :

```
grib_copy -w parameterCategory=3,parameterNumber=0 product.grb sst.grb
grib_copy -w parameterCategory=192,parameterNumber=1 product.grb conf.grb
grib_copy -w parameterCategory=192,parameterNumber=2 product.grb dtime.grb
```

Appendix A.4 : Locating the NAR data by using PROJ4 library

PROJ4 is a cartographic library accessible from C.

For more details see :

http://proj.maptools.org/

The following examples have been tested with the 4.5.0 version of the PROJ4 library. As they are demo programs no check of the return values is performed.

NAR_fwd : (longitude, latitude) → (column,line)

```
// NAR_fwd : Demo program showing how to compute the (column,line) point
// of the NAR grid corresponding to a (longitude,latitude) coordinates
// using the proj4 library.
// using the proj4 library.
// syntax : NAR_fwd lon lat
// where lon and lat are the longitude and latitude in degrees
// example :
// NAR_fwd -76.018069 43.765273
// lon=-76.018069 lat=43.765273 column=1.000000 line=1.000000
#include <stdlib.h>
#include <stdio.h>

#include <math.h>
#include <proj_api.h>

int main(int argc, char *argv[]) {

#define LON_ORG -76.018069 // longitude of first grid point is 76.018069W
#define LAT_ORG  43.765273 // latitude of first grid point is  43.765273N

#define DELTA_X  2000 // x direction grid length is 2 km ; scanningMode :
scan in +i direction
#define DELTA_Y -2000 // y direction grid length is 2 km ; scanningMode :
scan in -j direction

char str_proj[]="+proj=stere +a=6378160 +b=6356775 +lat_0=90 +lat_ts=45
+lon_0=0"; // proj4 string

double lon;
double lat;

lon=atof(argv[1]);
lat=atof(argv[2]);

// proj4 initialization
projPJ pj;
pj= pj_init_plus(str_proj);

// computing the (x,y) coordinates of the origin (1,1) grid point
```

```
projUV lp;
projUV xy;
double x_org;
double y_org;

lp.u=LON_ORG * DEG_TO_RAD;
lp.v=LAT_ORG * DEG_TO_RAD;
xy = pj_fwd(lp,pj);
x_org=xy.u;
y_org=xy.v;

// computing the (x,y) coordinates of the (lat,lon) position
double column;
double line;
lp.u=lon * DEG_TO_RAD;
lp.v=lat * DEG_TO_RAD;
xy = pj_fwd(lp,pj);
column= 1 + ( ( xy.u - x_org ) / DELTA_X );
line  = 1 + ( ( xy.v - y_org ) / DELTA_Y );

fprintf(stdout,"lon=%f lat=%f column=%f line=%f\n",lon,lat,column,line);

exit(0);

}
```

NAR_inv: (column, line) → (longitude,latitude)

```
// NAR_inv : Demo program showing how to compute the
// (longitude,latitude) coordinates of a (column,line) point of
// the NAR grid using the proj4 library.
// syntax : NAR_inv column line
// where column and line are the coordinates of the point
// 1<= column <=4096
// 1<= line <= 3072
// example :
// NAR_inv 1 1
// column=1.000000 line=1.000000 lon=-76.018069 lat=43.765273
#include <stdlib.h>
#include <stdio.h>

#include <math.h>
#include <proj_api.h>

int main(int argc, char *argv[]) {

#define LON_ORG -76.018069 // longitude of first grid point is 76.018069W
#define LAT_ORG  43.765273 // latitude of first grid point is  43.765273N

#define DELTA_X  2000 // x direction grid length is 2 km ; scanningMode :
scan in +i direction
#define DELTA_Y -2000 // y direction grid length is 2 km ; scanningMode :
scan in -j direction

char str_proj[]="+proj=stere +a=6378160 +b=6356775 +lat_0=90 +lat_ts=45
+lon_0=0"; // proj4 string
```

```
// getting the options
double column; // [1,4096]
double line;   // [1,3072]
column=atof(argv[1]);
line=atof(argv[2]);

// proj4 initialization
projPJ pj;
pj= pj_init_plus(str_proj);

// computing the (x,y) coordinates of the origin (1,1) grid point
projUV lp;
projUV xy;
double x_org;
double y_org;

lp.u=LON_ORG * DEG_TO_RAD;
lp.v=LAT_ORG * DEG_TO_RAD;
xy = pj_fwd(lp,pj);
x_org=xy.u;
y_org=xy.v;

// computing the (lon,lat) coordinates of the (column,line) igrid point
double lat;
double lon;
xy.u=x_org + DELTA_X * (column-1);
xy.v=y_org + DELTA_Y * (line  -1);
lp = pj_inv(xy,pj);
lon=lp.u * RAD_TO_DEG;
lat=lp.v * RAD_TO_DEG;

fprintf(stdout,"column=%f line=%f lon=%f lat=%f\n",column,line,lon,lat);

exit(0);

}
```